Table 4-93. Strontium-90 detection rates in sampled media.

Sampled Depth or Media	Detection Rate (%)	Range	Number of Detections >Risk-Based Concentration or MCL[a]	Wells with Detections >MCL
Vadose zone (0 to 35 ft):				
Core	15.2	0.13 to 0.92 pCi/g	0	None
Lysimeter	9.7	2.18 to 52.1 pCi/L	2	PA02, W06
Vadose zone (35 to 140 ft):				
Core	5.5	0.19 to 0.69 pCi/g	0	None
Lysimeter	7.1	4.12 pCi/L	0	None
Vadose zone (140 to 250 ft):				
Core	4.7	0.19 to 1.2 pCi/g	0	None
Lysimeter	2.3	9 pCi/L	1	USGS-92
Aquifer **(INEEL)**	1.0	0.12 to 2.5 pCi/L	0	M4D, M6S
Aquifer (USGS)	1.6	2.5 to 58 pCi/L	7[b]	USGS-87, USGS-88

MCL = maximum contaminant level
INEEL = Idaho National Engineering and Environmental Laboratory
USGS = U.S. Geological Survey
a. For vadose zone cores and surface soil samples, the calculated 1E-05 risk-based concentration is **55.1** 1 pCi/g. For lysimeter, perched water and aquifer samples, the aquifer MCL of **8** pCi/L is used for comparison only.
b. The number shown includes questionable detections from 1971 to 1972.

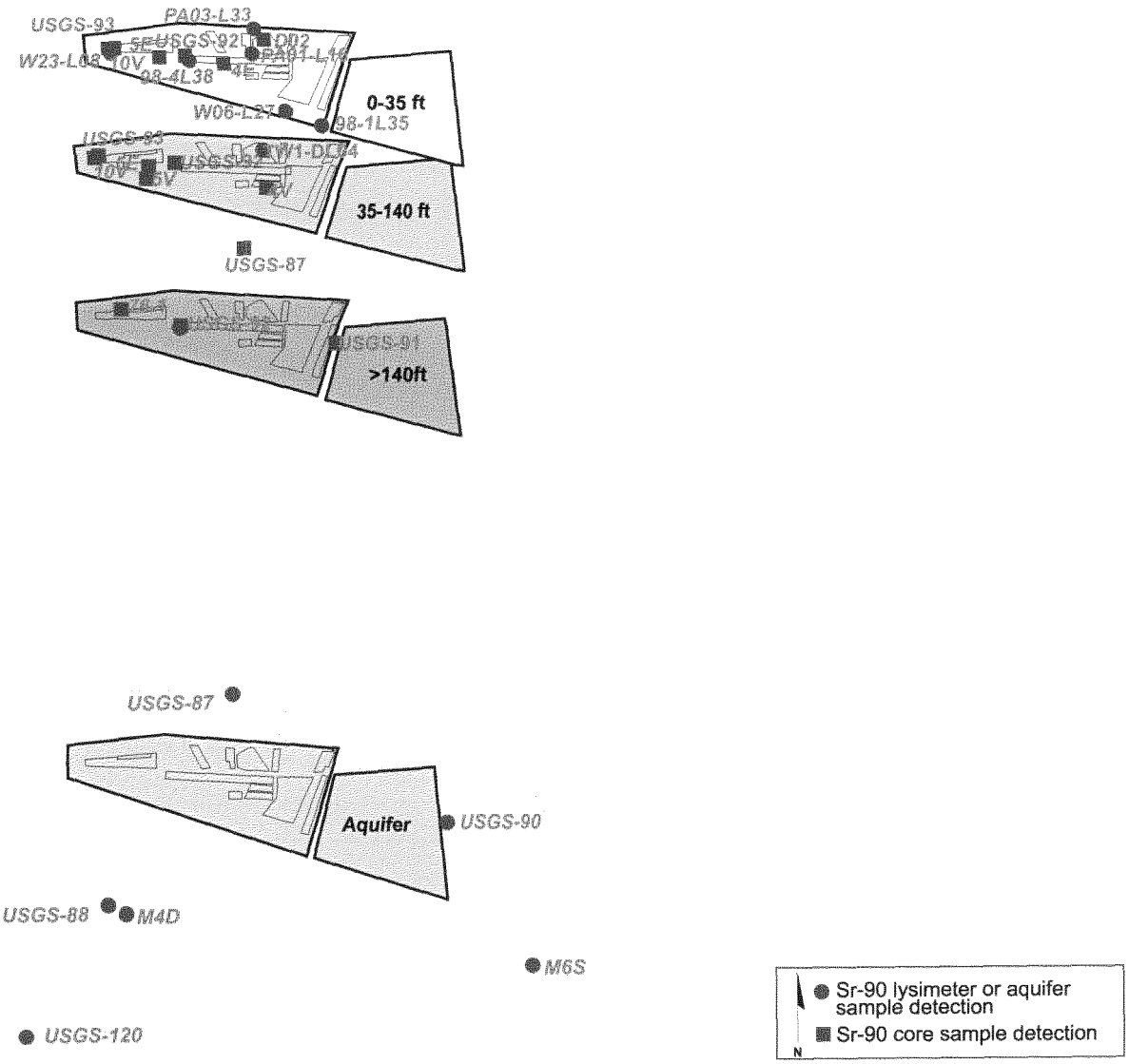

Figure 4-44. Locations of vadose zone core, lysimeter and aquifer samples with detectable concentrations of strontium-90, by depth interval.

Table 4-94. Comparison concentrations for technetium-99.

Surface Soil Background Concentration[a] (pCi/g)	Risk-Based Soil Concentration[b] (pCi/g)	Aquifer Background Concentration	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration[b] (pCi/L)
Not established	1,036	Not established	900	173

a. The value in this column represents the upper 95% tolerance limit with 95% confidence for composited surface **soil** (Rood, Harris, and White 1996).

b. Calculated risk-based concentration is equivalent to an increased cancer risk of **1E-05.**

Table 4-95. Waste streams containing technetium-99.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Idaho National Engineering and Environmental Laboratory (INEEL)	INEEL reactor operations waste	5.44E+01	89.9
Miscellaneous	Miscellaneous minor streams	2.12E+00	3.5
Argonne National Laboratory metal	Subassembly hardware	1.75E+00	2.9
Naval Reactors Facility	Test specimens	1.56E+00	2.6
D&D-ARA-1	Low-level waste from the decontamination and demolition of the Auxiliary Reactor Area facilities (primarily contaminated metal and debris)	6.42E-01	1.1
Total Disposals		6.05E+01	100

4.6.18.3 Vadose Zone

4.6.18.3.1 Vadose Zone Core Samples — A total of 52 vadose zone core samples were analyzed for Tc-99 between 1994 and 2000, yielding 19 positive detections (see Table 4-96). The Tc-99 detection rates per depth interval are indicated in Table 4-97. Earlier core samples collected from 1971 to 1993 were not analyzed for Tc-99.

Positive detections of Tc-99 were obtained from all "I" wells (inside the SDA) near the B-C and C-D interbeds. None of the "O" wells (outside the SDA), which were also collected in the 1999 to 2000 timeframe, had positive detections. Detection rates increased with depth down to 250 ft, though the number of samples is too few to draw conclusions about trends. Fifteen of the 19 positive Tc-99 results were qualified as questionable ("J" flagged) because the laboratory method blank also contained about 0.3 pCi/g of Tc-99, which biased the affected results approximately 12%. Therefore, Tc-99 may be present at these sample locations in low concentrations, or may not be present at all.

Table 4-96. Positive detections of technetium-99 from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration ± 1σ (pCi/g)	Date
I-1S	101.6 to 102.0	1.49 ± 0.18J[a]	1999 and 2000
	105.5	4.2 ± 0.4	1999 and 2000
	110.6 to 111.0	4.2 ± 0.4	1999 and 2000
I-1D	224.5 to 225.0	1.46 ± 0.19J	1999 and 2000
	237.6 to 238.0	2.5 ± 0.3J	1999 and 2000
	242.7 to 243.0	1.7 ± 0.25	1999 and 2000
1-2s	99.0 to 100.0	2.4 ± 0.3J	1999 and 2000
	111.0	3.3 ± 0.3	1999 and 2000
	112.5 to 113.0	1.8 ± 0.25	1999 and 2000
I-2D	223.5 to 224.0	2.1 ± 0.25	1999 and 2000
I-3S	99.0 to 101.0	1.08 ± 0.17J	1999 and 2000
I-3D	228.5 to 229.0	2.0 ± 0.35	1999 and 2000
	231.5 to 232.0	2.9 ± 0.35	1999 and 2000
I-4S	98.2 to 98.8	2.3 ± 0.3J	1999 and 2000
I-4D	223.0 to 223.6	2.9 ± 0.3J	1999 and 2000
	229.6 to 230.0	3.1 ± 0.35	1999 and 2000
	237.0 to 237.5	3.0 ± 0.35	1999 and 2000
	237.5 to 238.0	3.4 ± 0.3	1999 and 2000
I-5S	103.5 to 104.0	1.8 ± 0.2J	1999 and 2000

a. Some of the data were "J" flagged because of low concentrations detected in the sample **blank.** See text for discussion.

Table 4-97. Summary of technetium-99 occurrences in the vadose zone core samples.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Range (pCi/g)	Wells or Borehole with Detection
0 to 35	0/11 (0)	Not applicable	Not applicable
35 to 140	9/25 (36.0)	1.08 to 4.2	I-1S, I-2S, I-3S, I-4S, 1-5S
140 to 250	10/16 (62.5)	1.46 to 3.4	I-1D, I-2D, I-3D, I-4D
More than 250	0/0	Not applicable	Not applicable

4.6.18.3.2 Lysimeter Samples at Depths of 0 to 35 ft—A total of 82 shallow lysimeter samples were analyzed for Tc-99 between 1997 and May 2001, resulting in 16 detections (see Table 4-98).

The positive detections were not confirmed by reanalysis of the original sample. The occurrence of the detections relative to the nondetections is shown in Figure 4-45.

Five out of six results from Lysimeter W23-LO9 (8 ft deep) contained detectable amounts of Tc-99, and the June 2000 sample from Lysimeter W23-LO8 (12 ft deep) in the same borehole also contained detectable Tc-99, suggesting movement in the vadose zone may be occurring. In addition, three out of

Table 4-98. Detected concentrations of technetium-99 in shallow lysimeters.

Lysimeter	Depth (ft)	Concentration ± 1σ (pCi/L)	Confirmation Flag[a]	Date
W23-LO8	11.8	39 ± 6	A	June 2000
		46 ± 7	A	May 2001
W23-LO9	14.8	17 ± 4	A	April 1997
		30 ± 5	A	August 1997
		20 ± 2	B	August 1998
		20 ± 4	A	March 2000
		33 ± 5	A	June 2000
WO8-L13	11.3	15 ± 5	A	June 2000
PA01-L15	14.3	17 ± 5	A	June 2000
		27 ± 4	B	September 2000
PAO2-L16	8.7	13 ± 3	B	December 1998
PA03-L33	10.0	36 ± 5	A	December 1998
		21 ± 3	A	November 1999
		17 ± 4	A	March 2000
98-lL35 (SDA-01)	16.5	16 ± 4	A	June 2000
98-5L39 (SDA-10)	10.5	21 ± 5	A	June 2000

a. Confirmation flag:
A = No second sample collected, no reanalysis performed.
B = Reanalysis performed, no confirmation.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01-L15	PA02-L16	PA03-L33	W06-L27	W08-L13	W08-L14	W23-L08	W23-L09	W25-L28
1997	1												
	2											17	
	3											30	
	4												
1998	1												
	2												
	3											20	
	4						36						
1999	1												
	2												
	3												
	4						21						
2000	1						17					20	
	2	16		21	17				15		39	33	
	3				27								
	4												
2001	1												
	2										46		
	3												
	4												
Key			Tc-99 was analyzed for, but not detected.										
			Tc-99 was detected (pCi/L).										
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-45. Occurrence of technetium-99 detections in shallow lysimeters.

four samples from Lysimeter PA03-L33 have contained detectable amounts of Tc-99. The presence of Tc-99 is corroborated by numerous positive detections of Tc-99 in the vadose zone core samples from the "T" wells, which are inside the SDA boundary. Soil moisture with elevated Tc-99 concentrations and noticeable trends are primarily isolated to two distinct locations, the west end and the north-central portion, of the SDA.

None of the positive results exceeded the MCL of 900 pCi/L used for comparison. Though the Tc-99 results and trend data imply some release may be occurring, the data do not support a clear conclusion.

4.6.18.3.3 Lysimeter Samples at Depths of 35 to 140 ft—A total of 22 lysimeter samples were analyzed for Tc-99 between 1996 and May 2001, with four positive detections (see Table 4–99).

Table 4-99. Detected concentrations of technetium-99 in the 35 to 140-ft interval of the vadose zone.

Lysimeter	Depth (ft)	Concentration ± 1o (pCi/L)	Confirmation Flag[a]	Date
D06-DLO1	88	11 ± 2	A	August 1998
D06-DL02	44	33 ± 3	A	August 1998
D15-DL06	98	5.8 ± 1.3	A	April 1996
		21 ± 7	A	June 2000

a. Confirmation flag:
A = No second sample collected, no reanalysis performed.

The positive sample results could not be confirmed by reanalysis because of the limited sample volumes available. Subsequent samples collected from these three wells through May 2001 have not shown Tc-99 detections. Of the eight other lysimeter wells sampled, none had detectable amounts of Tc-99. None of the detected concentrations exceed the MCL used for comparison.

4.6.18.3.4 Lysimeter and Perched Water Samples at Depths Greater than 140 ff—A

total of 15 water samples and eight filtered sediment samples from perched water and lysimeter wells were analyzed for Tc-99 between 1997 and December 2000. There were three positive detections, two of the filtered sediments and one of the liquid. The sediment samples did not exceed the 1E-05 risk-based concentration for soil, and the liquid sample did not exceed the MCL of 900 pCi/L (see Table 4-100).

The September 2000 water sample result was not confirmed by reanalysis of the original sample. The one subsequent water sample from Well USGS-92 in December 2000 did not contain detectable Tc-99. The USGS does not analyze samples from perched water Well USGS-92 for Tc-99. Though the concentration in the liquid fraction was relatively high, the result was not confirmed via reanalysis.

Table 4-100. Positive detections of technetium-99 from lysimeters and perched water wells.

Lysimeter or Perched Water Well	Concentration ± 1σ (pCi/L) Water	Confirmation Flag	Concentration ± 1σ (pCi/g) Filtered Sediments	Confirmation Flag"	Date
USGS-92	Not applicable	Not applicable	1.25 ± 0.17	**A**	December 1998
	280 ± 37	**A**	3.1 ± 0.4	**A**	September 2000

a. Confirmation **flag:**
A = No second sample collected, no reanalysis performed.

4.6.18.4 Aquifer. A total of 240 aquifer well samples from four RWMC area aquifer wells were collected and analyzed for Tc-99 between 1994 and April 2001. There were five positive detections of Tc-99 (see Table 4-101). None of the positive results exceeded the MCL.

Table 4-101. Detected concentrations of technetium-99 in aquifer samples around the Radioactive Waste Management Complex.

Aquifer Well	Concentration ± 1σ (pCi/L)	Confirmation Flag[a]	Date
M3S	1.4 ± 0.3	**A**	April 1997
M4D	9.0 ± 2.5	B	April 1996
M6S	1.0 ± 0.3	**A**	April 1997
M17S	**1.5 ± 0.4**	D	May 2000
	35 ± 5	D	May 2000

a. Confirmation flag:
A = No second sample collected, no reanalysis performed.
B = Reanalysis performed, no confirmation.
D = Detection confirmed by reanalysis.
Note: Highlighted values **and** the **"D"** confirmation flag indicate that the positive detection was confirmed.

Only the May 2000 Tc-99 detection for Well M17S was confirmed by reanalysis of the original sample, but the positive result did not agree with the original analysis. **As** shown in Figure 4-46, subsequent samples collected from the four aquifer wells have not yielded positive detections.

The **USGS** does not analyze for Tc-99 in the eight RWMC wells they manage, control, and routinely sample.

4.6.18.4.1 Summary of Technetium-99 — Vadose zone core samples were collected inside and outside of the SDA to determine whether Tc-99 and other radionuclides were present. All of the vadose zone cores taken within the SDA contained detectable amounts of Tc-99 at some depth, while none of the cores outside the SDA boundary contained detectable Tc-99. The Tc-99 detection rates for all sampled media are indicated in Table 4-102.

Technetium-99 has been detected in the aquifer, but no trends are evident. However, Tc-99 is a mobile contaminant and has been detected in some of the lysimeter and perched water well samples from the SDA. As shown in Table 4-102, the detection rates remain relatively constant over depth in the vadose zone but drop dramatically to 2.1% in the aquifer wells. Locations of the detections of Tc-99 in the vadose zone cores, lysimeters, and aquifer samples are shown in Figure 4-47.

Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11A31	OW-2
1994	1															
	2															
	3															
	4															
1995	1															
	2															
	3															
	4															
1996	1															
	2			9.0												
	3															
	4															
1997	1															
	2		1.4		1.0											
	3															
	4															
1998	1															
	2															
	3															
	4															
1999	1															
	2															
	3															
	4															
2000	1															
	2													35		
	3															
	4															
2001	1															
	2															
	3															
	4															
Key			Tc-99 was analyzed for, but not detected.													
			Tc-99 was detected (pCi/L).													
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.														

Figure 4-46. Aquifer monitoring detections of technetium-99, 1994 through April 2001.

Table 4-102. Technetium-99 detection rates in all sampled media.

Media or Depth Interval	Detection Rate (%)	Range	Total Number of Samples >Risk-Based Concentration or MCL[a]	Location of Samples >Risk-Based Concentration or MCL
Vadose zone (0 to 35 ft)				
Core	0	Not applicable	0	None
Lysimeter	19.5	13 to 46 pCi/L	0	None
Vadose zone (35 to 140 ft)				
Core	36.0	1.08 to 4.2 pCi/g	0	None
Lysimeter	18.2	5.8 to 33 pCi/L	0	None
Vadose zone (140 to 250 ft)				
Core	62.5	1.46 to 3.4 pCi/g	0	None
Lysimeter/Well	13.0	280	0	
Vadose zone (>250 ft)				
Core	Not applicable	Not applicable	Not applicable	Not applicable
Lysimeter	Not applicable	Not applicable	Not applicable	Not applicable
Aquifer (INEEL)	2.1	1.0 to 35 pCi/L	0	0

MCL = maximum contaminant level
INEEL = Idaho National Engineering and Environmental Laboratory
a. Vadose zone cores are compared with the E-05 risk-based concentration for soil (1,036 pCi/L); soil moisture, perched water, and aquifer samples compared to the maximum contaminant level of 900 pCi/L.

4.6.19 Uranium

Uranium is a radioactive element that occurs naturally in the environment as three principal isotopes (U-234, U-235, and U-238). Uranium-238 and U-235 are the parent isotopes of two independent decay series, while U-234 is a decay product of the U-238 decay series. Uranium also is processed and handled by human beings for use in nuclear weapons and nuclear reactors and contains four principal isotopes (U-234, U-235, U-236, and U-238). Uranium-234, U-235, U-236, and U-238 decay by the emission of alpha particles and gamma rays, with half-lives of 2.46E+05, 7.04E+08, 2.34E+07, and 4.47E+09 years, respectively. Uranium-233 is an isotope that does not occur naturally and is not produced during the enrichment process. It is produced in small quantities from the decay of Am-241 and in significant quantities in nuclear reactors that use thorium fuel. The properties of the natural uranium isotopes are shown in Table 4-103. Uranium isotopes are identified in the IRA as COPCs, primarily for the groundwater ingestion exposure pathway (Becker et al. 1998). Available information about the presence of uranium in the SDA and available uranium monitoring data for all media were reviewed for this report and are summarized below.

Because uranium is naturally occurring, identifying background concentrations was necessary to determine whether the INEEL samples contained contamination. Recognizing this, studies have been conducted to identify uranium background concentrations of U-234 and U-238 in soil (Rood, Harris, and White 1996) and of total uranium in the aquifer (Knobel, Orr, and Cecil 1992).

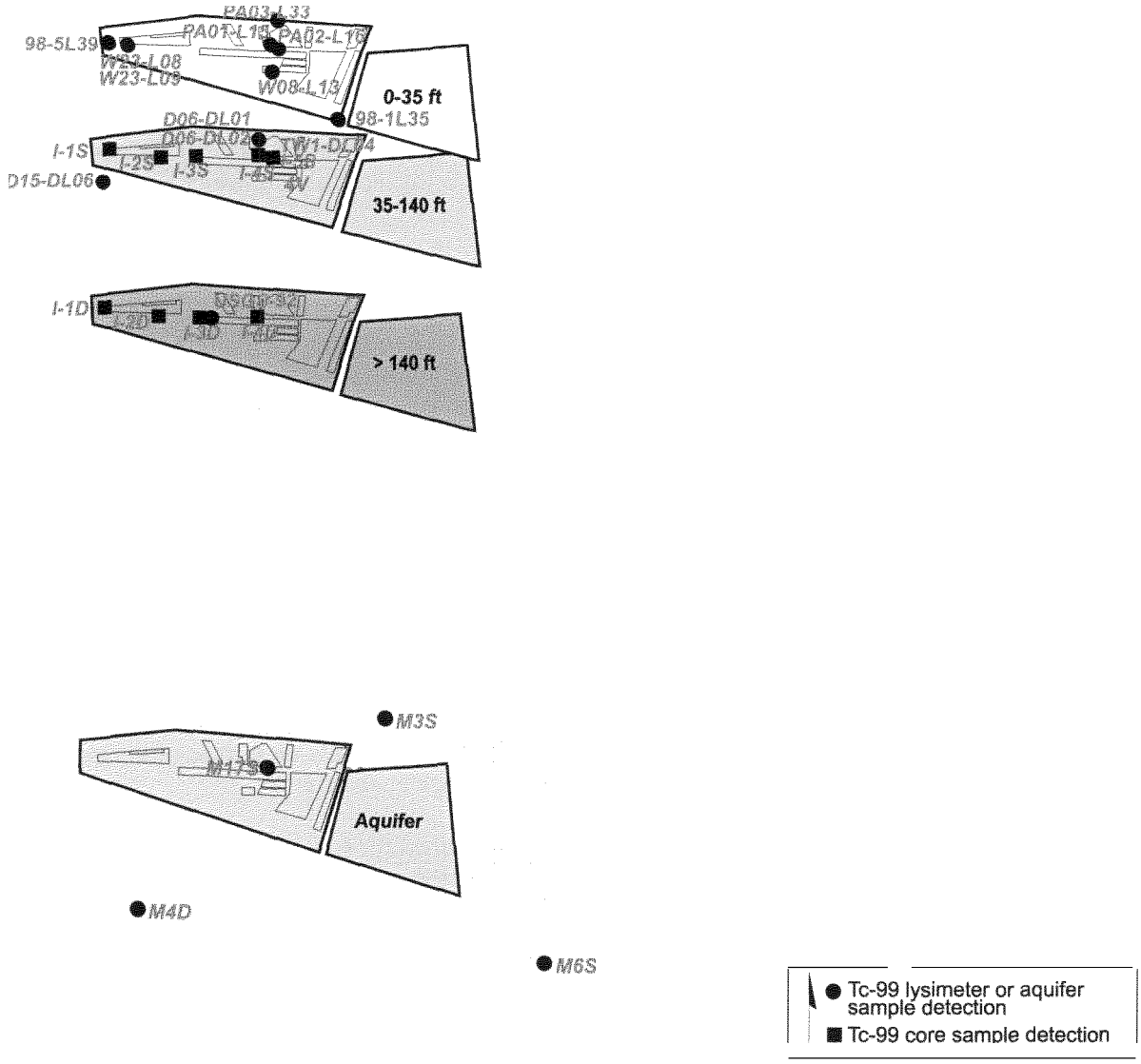

Figure 4-47. Locations of vadose zone core, lysimeter and aquifer samples with detectable concentrations of technetium-99, by depth interval.

Table 4-103. Properties of the natural uranium isotopes.

Property	U-234	U-235	U-238
Half-life (years)	2.46E+05	7.04E+08	4.47E+09
Specific Activity (pCi/g of isotope)	6.19E+09	2.13E+06	3.36E+05
Activity in 1 g uranium$_{nat}$ (pCi)	3.40E+05	1.55E+04	3.34E+05
Natural abundance (activity %)	49.3	2.3	48.4

The USGS established background concentrations of total uranium in the SRPA (Knobel, Orr, and Cecil 1992) using 72 samples from wells in the Magic Valley (i.e., in the vicinity of Twin Falls, Idaho). According to the USGS study, the background for total uranium **in** the Snake River Plain Aquifer is about

0 to 3.35 µg/L, which equates to about 0 to 1.1 pCi/L for U-234 and U-238, and about 0.05 for U-235, after adjusting for specific activity and the relative abundance of each isotope in the earth's crust.

Background uranium concentrations identified in Knobel, Orr, and Cecil (1992) may not be applicable to the INEEL background aquifer concentrations for several reasons. The background concentrations for U-234 appear to be too low for INEEL or RWMC application, which may be caused by the following:

- The method of converting and estimating uranium isotopic concentrations from the total uranium concentrations reported by the USGS. The U-234, U-235, and U-238 concentrations used in this document were calculated from the mean value of 3.35±0.18 µg/L for total U reported by the USGS (Knobel, Orr, and Cecil 1992). The isotopic concentrations were converted from total uranium (µg/L) by using the specific activity of each isotope and the known natural abundance of each uranium isotope in the earth's crust. The concentrations were based on the assumption that U-234 abundance is 0.0058%. Deviation from this proportion would affect the U-234 concentration.

- The isotopic components of uranium in the aquifer in the Magic Valley differ from the composition of the aquifer beneath the INEEL. Roback et al. (September 2001) determined that U-234 and U-238 vary considerably in the SRPA in the vicinity of the INEEL, and natural U-234:U-238 ratios may vary by a factor of two or more in the aquifer. Results of the Magic Valley samples are based on total uranium and do not account for varying concentrations of U-234 and U-238.

Future examination of uranium contamination in the SRPA could rely on the use of the more recent uranium isotopic background concentrations developed by Roback et al. (2001).

Because no background concentrations have been determined for soil moisture or perched water samples, a local background concentration was estimated using the mean of sample concentrations from wells just outside the SDA (i.e., the "O" wells) and from Well D15, a designated local background site.

The vadose zone core data from background locations around the RWMC correlate well with the relative abundance of the various uranium isotopes in the earth's crust. Obtaining precise numbers for U-235 is difficult because U-235 background is relatively low and the analytical techniques used on routine samples measure near the detection limit. To obtain low-level analytical data for U-235 and U-236 to help identify uranium sources as natural, depleted, or enriched, a set of lysimeter samples was submitted for TIMS analysis to achieve ultra low-level detection limits and uncertainties. The U-235 and U-236 results were used to calculate precise uranium isotopic ratios for U-234:U-238, U-236:U-238, and U-238:U-235.

The typical isotopic composition associated with enriched, depleted, and natural uranium is shown in Table 4-104, and typical ratios are shown in Table 4-105. Enriched uranium refers to natural uranium (ore) that has been processed to increase the concentration of U-235. The enrichment process (gaseous diffusion technology most commonly used in the United States) removes the U-238, which increases the concentration of both U-234 and U-235 (DOE-STD-1136-2000). The by-product of the enrichment process (U-238) is referred to as depleted uranium.

Table 4-104. Typical isotopic composition of anthropic uranium (% by weight).

Form	U-234	U-235	U-236	U-238
Enriched (high)	1.0%	93.1%	0.4%	5.5%
Enriched (low)	0.03%	2.97%	0.00%	97.00%
Depleted	0.001%	0.22%	0.000%	99.78%

Table 4-105. Uranium ratio guideline for estimating potential uranium sources.

		Atomic Mass Guideline Ratios			Radioactivity Guideline Ratios	
Category		U-234/238 (INEEL Groundwater)[a]	U-234/238	U-238/235	U-234/238	U-238/235
Depleted	(0.2%)	<<8.60E-05	<<5.5E-05	–500	~ 0.1	~ 77
Depleted	(0.4%)	<8.60E-05	<5.5E-05	–250	Not established	~ 39
Natural	(0.7%)	8.60E-05 to 1.66E-04	5.5E-05	–138	– 1	~ 22
					~ 1.5 to 3[a]	~ 22
Enriched	(2%)	>1.66E-04	>5.5E-05	–50	Not established	– 8
Enriched	(93%)	>>1.66E-04	>>5.5E-05	–0.08	~ 3,000	~ 0.01

INEEL = Idaho National Engineering and Environmental Laboratory
a. Uranium-234/238 are not in secular equilibrium in groundwater beneath the Idaho National Engineering and Environmental Laboratory (Johnson et al. 1998).

The U-238 and U-235 ratio could not be calculated on routine environmental samples because the concentrations of U-235 are generally too low for reliable measurement with routine radioanalytical techniques. However, the concentrations of U-233/234 and U-238 are typically high enough for consistent detection and precision. Therefore, the U-234:U-238 ratio is the only ratio that is routinely assessed in WAG 7 investigations. When measurable concentrations of U-235 are present, the U-238:U-235 ratios are assessed.

All of the uranium isotopes were identified as COPCs in the IRA, primarily from the groundwater ingestion exposure pathway (Becker et al. 1998).

The sampling results reported by the laboratory generally are combined for U-233/234 and U-235/236. These pairs of isotopes are combined because they cannot be chemically separated and they have alpha particle energies that are nearly identical. Therefore, they are nearly impossible to differentiate in environmental level samples using routine alpha spectroscopy. If obtaining results for each separate radionuclide becomes necessary, analysis by a nonradiochemical methodology (i.e., mass spectrometry) would be required.

The sampling data in this section are evaluated against the comparison concentrations in Table 4-106.

Table 4-106. Comparison concentrations for uranium.

Contaminant	Soil 1E-05 Risk-Based Concentration (pCi/g)	Background INEEL Soil" (pCi/g)	Local Soil Moisture Background[b] (pCi/L)	Background Aquifer' (pCi/L)	Aquifer 1E-05 Risk-Based Concentration (pCi/L)	Maximum Contaminant Level (pCi/L)
U-233	49.60	Not established	Not established	Not established	6.63	27 (total naturally occurring uranium)
U-234	50.23	1.44	3	1.1	6.74	
U-235	48.69	0.103[d]	0.5	0.05	6.63	
U-236	53.27	Not established	Not established	Not established	7.11	
U-238	37.79	1.4	1.5	1.1	5.47	

INEEL = Idaho National Engineering and Environmental Laboratory
a. Upper 95%/95% tolerance limit with 95% confidence for composite surface soils on the INEEL (Rood, Harris, and White 1996).
b. Local soil moisture background is the mean of the concentrations in the "O" wells (outside of the SDA) and of Well D15, a designated background location.
c Calculated from the mean uranium concentration of 3.35 ug/L from Knobel, Orr and Cecil 1992.
d. Background U-235 concentration in soil is based on the Radiological and Environmental Sciences Laboratory maximum background soil concentration cited in Rood, Harris, and White (1996, Table 4).

4.6.19.1 Waste Zone

4.6.19.1.1 Inventory — The following estimated quantities of uranium isotopes were disposed of at the SDA:

- 1.51 Ci of U-233
- 67.4 Ci of U-234
- 5.54 Ci of U-235
- 2.86 Ci of U-236
- 117 Ci of U-238.

Additional quantities of uranium are generated over time by ingrowth (see Section 4.1.2). Tables 4-107 through 4-1 11 show the waste streams containing uranium disposals. Also included is the amount of uranium that would be produced if all of the parent were allowed to decay. Percentages of the total uranium from parent isotopes are not given because the amount of uranium present is dependant on the timeframe assessed. In addition, many of the uranium isotopes decay into other isotopes of interest. Specifically, U-233 is generated by the decay of Pu-241, Am-241 and Np-237 and U-233 decays into Th-229. Uranium-234 is generated by the decay of U-238 and Pu-238 and U-234 decays into Th-230, Ra-226, and Pb-210. Uranium-235 is generated by the decay of Am-243 and Pu-239 and decays into Pa-231 and Ac-227. Uranium-236 is generated by the decay of Pu-240 and decays into Th-232 and Ra-228.

Table 4-107. Waste streams containing U-233.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
ARA-626-1H	Fuel scrap, waste from disassembly of facilities and hot cell waste	6.00E-01	39.8
RFO-DOW-19H	Miscellaneous scrap	5.4E-01	35.9
SMC-628-2	Unsolidified slag	3.01E-01	19.9
SMC-990-1	Depleted uranium-contaminated material (e.g., metals, glass, and gravel)	2.74E-02	1.8
SMC-628-1	Nonacidic evaporator sludge	2.21E-02	1.5
Miscellaneous	Miscellaneous minor streams	1.66E-02	1.1
Total Disposals		1.51E+00	100
Pu-241 ingrowth	Half-life equals 14.4 years. See Section 4.6.13	8.82E+01	NA
Am-241 ingrowth	Half-life equals 432 years. See Section 4.6.2	4.97E+02	NA
Np-237 ingrowth	Half-life eauals 2.14E+06 vears. See Section 4.6.10	3.56E+01	NA

4.6.19.1.2 Gamma Logging—The spectral gamma-logging tool provides no information about U-234.

The spectral gamma-logging tool detected U-235 based on the 186-keV gamma, and U-238 based on the 1,001-keV gamma emitted by its progeny Pa-234m. The detection rates above the noise level for probeholes and individual samples, and other detection data are shown in Table 4-112.

Table 4-108. Waste streams containing uranium-234.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-18H	Enriched uranium	2.15E+01	31.9
RFO-DOW-16H	Depleted uranium	1.45E+01	21.5
CPP-601-3H	Dissolved fuel specimens	4.70E+00	7.0
Miscellaneous	Miscellaneous minor streams	4.65E+00	6.9
PDA-RFO-1A	Inorganic salts, depleted uranium, and sewage sludge	4.64E+00	6.9
OFF-ATI-1H	Irradiated fuel from research	3.64E+00	5.4
ANL-EBRI-1H	Miscellaneous combustibles and core, vessel, and loop components	3.36E+00	5.0
OFF-GEC-1H	Core, vessel, and loop components	2.95E+00	4.4
TAN-607-2	Test Area North Hot Shop noncompactable waste	1.83E+00	2.7
ANL-752-1R	Contact-handled waste	1.33E+00	2.0
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	1.30E+00	1.9
ANL-704-1R	Contact-handled fuel fabrication waste	1.21E+00	1.8
TRA-603-15H	Metal	1.11E+00	1.6
ALE-317-2R	Combustibles	7.10E-01	1.1
Total Disposals		67.43	100
U-238 ingrowth	Half-life equals 4.47E+09 years. See Section 4.6.19	2.14E+06	NA
Pu-238 ingrowth	Half-life equals 8.78E+01 years. See Section 4.6.13	6.13E+00	NA

4.6.19.1.3 Uranium-235/236—A total of 186 soil samples were collected between 1994 and 2000 from in and around the RWMC. Based on gamma spectrometric analytic results, 76 were selected for U-235 analysis. Fourteen positive detections of U-235 were documented. The positive results ranged from (4.4 ± 0.9) E-02 pCi/g at Pad A to (6.2 ± 1.4) E-02 pCi/g at the active area (LMITCO 1995c).

A total of 124 vegetation samples were collected between 1990 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 30 samples were selected for U-235 analysis. No positive detections of U-235 were documented.

A total of 210 surface run-off water samples were collected between 1991 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 93 samples were selected for U-235 analysis. No positive detections of U-235 were documented.

4.6.79.7.4 ***Uranium-238***—A total of 186 soil samples were collected between 1994 and 2000 from the RWMC area. Based on gamma spectrometric analytic results, 76 were selected for U-238 analysis. The 19 positive detections ranged in concentration from (1.1 ± 0.2) E-01 pCi/g (active area) to 1.61 ± 0.27 pCi/g (north of the administrative area) (LMITCO 1997). None of the samples exceeded the 1E-05 risk-based concentration for soil.

Table 4-109. Waste streams containing uranium-235.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-16H	Depleted uranium	1.08E+00	19.5
TRA-603-16H	Combustibles	7.80E-01	14.1
RFO-DOW-18H	Enriched uranium	7.44E-01	13.4
Miscellaneous	Miscellaneous minor streams	6.26E-01	11.3
TRA-603-15H	Metal	5.35E-01	9.7
TRA-603-6H	Core, vessel, and loop components	4.02E-01	7.3
PDA-RFO-1A	Inorganic salts, depleted uranium and sewage sludge	3.25E-01	5.9
WAG-WG7-02	Acid Pit in situ stabilization treatability study waste	1.80E-01	3.3
OFF-GEC-1H	Core, vessel, and loop components	1.57E-01	2.8
CPP-601-3H	Dissolved fuel specimens	1.50E-01	2.7
INEEL	INEEL reactor operations waste	1.28E-01	2.3
OFF-ATI-1H	Irradiated fuel from research	1.14E-01	2.1
ANL-EBRI-1H	Miscellaneous combustibles and core, vessel, and loop components	1.10E-01	2.0
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	8.00E-02	1.4
OFF-GDA-1H	Fuel fabrication item, laboratory equipment, activated metal and irradiated fuel	7.00E-02	1.3
ANL-752-1R	Contact-handled waste	5.60E-02	1.0
Total Disposals		5.54E+00	100
Am-243 ingrowth	Half-life equals 7.83E+03 years. See Section 4.6.3.	1.41E-03	NA
Pu-239 ingrowth	Half-life equals 2.41E+04 years. See Section 4.6.13.	2.22E+00	NA

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-110. Waste streams containing uranium-236.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total (%)
RFO-DOW-16H	Depleted uranium	9.03E-01	31.5
INEEL	INEEL reactor operations waste	5.83E-01	20.4
TRA-603-15H	Metal	4.22E-01	14.7
TRA-603-1H	Resins	2.7E-01	9.4
TRA-642-6H	Core, vessel, and loop components	2.44E-01	8.5
TRA-603-4H	Core and loop components	1.07E-01	3.7
TRA-603-9H	Expended fuel and ceramic fuel	8.11E-02	2.8
RFO-DOW-18H	Enriched uranium	8.04E-02	2.8
Miscellaneous	Miscellaneous minor streams	7.44E-02	2.6
NRF	Test specimens	5.29E-02	1.8
SMC-628-2	Unsolidified slag	4.37E-02	1.5
Total Disposals		2.86E+00	100
Pu-240 ingrowth	Half-life equals 6.57E+03 years	4.80E-00	NA

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-111. Waste streams containing uranium-238.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-16H	Depleted uranium	7.62E+01	65.0
PDA-RFO-1A	Inorganic salts, depleted uranium, and sewage sludge	2.49E+01	21.2
Miscellaneous	Miscellaneous minor streams	8.20E+00	7.0
SMC-628-2	Unsolidified slag	2.31E+00	2.0
ARA-627-1H	Fuel scrap, waste from disassembly of facilities, and hot cell waste	1.64E+00	1.4
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	1.32E+00	1.1
ALE-ALE-1H	Building rubble, electric wires, piping, machinery, tracers and sources, glass, gloves, paper, filters, and vermiculite	1.32E+00	1.1
INEEL	INEEL reactor operations waste	1.30E+00	1.1
Total Disposals		117.19	100

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-112. Detection rates for uranium-235 and uranium-238 from the gamma logging tool.

Isotope	Probehole Detection Rate (%)	Measurement Detection Rate (%)	Detection Limit (pCi/g)	Number Above E-05 Risk-Based Concentration	Number Above Background	Maximum Concentration (pCi/g)	Average Concentration (pCi/g)	Median (pCi/g)
U-235	441135 (33%)	26114863 (5%)	2	25	Not applicable	345	22	8
U-238	701135 (52%)	86214863 (18%)	25	640	862	220,894	2,300	109

A total of 124 vegetation samples were collected between 1990 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 30 samples were selected for U-238 analysis. The nine positive detections of U-238 ranged in concentration from (1.98 ± 0.44) E-03 pCi/g (TSA) (INEEL 2000) to (2.79 ± 0.51) E-02 pCi/g (active area) (LMITCO 1998).

A total of 210 surface run-off water samples were collected between 1991 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 93 samples were selected for U-238 analysis. The six positive detections ranged in concentration from (2.61 ± 0.86) E-02 pCi/L (TSA-3) (LMITCO 1998) to (3.69 ± 0.82) E-01 pCi/L (Control T-12) (LMITCO 1998).

4.6.19.2 Vadose Zone

4.6.19.2.1 Uranium in Vadose Zone Core Samples — Vadose zone core samples have been collected around the RWMC during several sampling campaigns. Core samples identified as sedimentary interbed have U-234 and U-238 concentrations that are near 1 pCi/L, which is typical of naturally occurring uranium in soils and sediments. However, core samples identified as massive basalt, fractured basalt, and rubble zone have U-234 and U-238 concentrations at much lower concentrations (0.1 to 0.2 pCi/g).

4.6.19.2.1.1 Uranium-233/234—A total of 87 vadose zone core samples were analyzed for U-233/234 between 1971 and 2000, with 47 positive detections. These 87 included 32 samples from 1999 to 2000, and 55 from the earlier campaigns, when reported values were unusually low (see Section 4.6.16.3.1). Only one of the 87 samples exceeded a background concentration of 1.44 pCi/g (Table 4-113), and none exceeded the soil risk-based concentration of 50.23 pCi/g for U-234.

Table 4-113. Summary of uranium-233/234 occurrences greater than background in the vadose zone core samples.

Depth Interval (ft)	Number Detections/Number of Samples (%)	Number of Detections >Background[a] /Number of Samples (%)	Range of concentrations >Background (1.44 pCi/g)	Wells and Boreholes with Detections >Background
0 to 35	3/11 (27.0)	0/11 (0)	Not applicable	Not applicable
35 to 140	22/40 (55.0)	1/40 (2.5)	1.7	76-4
140 to 250	22/36 (61.1)	0136 (0)	Not applicable	Not applicable
More than 250	0/0	0/0 (NA)	Not applicable	Not applicable

a. Background U-233/234 for Idaho National Engineering and Environmental Laboratory surface soil is 1.44 pCi/g (Rood, Hams, and White 1996).

4.6.19.2.1.2 Uranium-235/236—A total of 86 vadose zone core samples were analyzed for U-235/236, with 12 detections. One slightly exceeded a background of 0.103 pCi/g, and none exceeded the 1E-05 soil risk-based concentration of 48.7 pCi/g for U-235. The detection rates for the various depth intervals are shown in Table 4-114.

Table 4-114. Summary of U-235/236 detections above background concentrations in vadose zone core samples.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Number of Detections Above Background[a]/Number of Samples (%)	Range of Concentrations > Background (0.103 pCi/g)	Wells and Boreholes with Detections > Background
0 to 35	0/9 (0)	0/9 (0)	Not applicable	None
35 to 140	5/41 (12.2)	0/41 (0)	Not applicable	None
140 to 250	7/36 (19.4)	1/36 (2.8)	0.120	I-3D
More than 250	0/0 (0)	0/0 (0)	Not applicable	None

a. Background U-235 for Idaho National Engineering and Environmental Laboratory surface soil is 0.103 pCi/g (Rood, Harris, and White 1996).

4.6.19.2.1.3 Uranium-238—A total of 96 vadose zone core samples were analyzed for U-238, with 62 detections. Thirty-two of the samples were analyzed in 1999 and 2000 (all had detected concentrations of U-238). The other 64 samples were analyzed between 1971 and 1993. Of those, 53 were analyzed in 1993 and were all qualified as questionable ("J" flagged) because the laboratory method blank contained detectable (0.2 pCi/g) U-238. Of the 53 samples from 1993, 17 of them were documented as positive detections after adjusting for the contamination in the laboratory method blank (0.2 pCi/g). Positive results are presented here even though the laboratory method blank contained detectable U-238 because the concentration of the blank was minimal (0.2 pCi/g) compared to the sample results.

Six of the 62 positive detections were above the INEEL surface soil background of 1.40 pCi/g established by Rood, Harris, and White (1996) (Table 4-115). The background exceedance rates for the various depth intervals are shown in Table 4-116. All of the results above background were among the "J" flagged data set.

4.6.19.2.1.4 Uranium Ratios in *the* Vadose Zone Core Samples— The concentration or activity ratio of U-233/234:U-238 can be used to evaluate whether the uranium in a sample **is** natural uranium or uranium from waste, and whether the uranium from waste is enriched (higher U-233/234:U-238 ratio) or depleted (lower ratio) (see Section 4.6.16). Uranium-233/234:U-238 activity ratios were between 0.8 and 1.1 for the 1999 and 2000 vadose zone core data, which is expected for samples that contain only natural uranium. Ratios were not calculated on the data that were collected prior to 1999 because many of the samples were identified as massive basalt, fractured basalt and rubble, and many of the concentrations in those data sets were too low to provide reliable detections.

Table 4-115. Uranium-238 concentrations above background from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration[a] ± 1o (pCi/g)	Date
76-4	99.9	1.7 ± 0.10[b]	1993
USGS-91	23.4 to 25.0	5.4 ± 0.2[b]	I993
8802D	95.0 to 96.0	2.70 ± 0.10[b]	1993
USGS-94	116.3 to 118.0	5.9 ± 0.2[b]	1993
	217.0 to 220.2	7.5 ± 0.2[b]	1993
USGS-93	222.5 to 236.0	2.80 ± 0.10[b]	1993

a. Background is 1.40 pCi/g (Rood, Harris, and White 1996).
b. Data are questionable because of **method blank contamination.**

Table 4-116. Summary of U-238 occurrences greater than background in the vadose zone core samples.

Depth Interval (ft)	Number of U-238 Detections/Total Number of Samples (%)	Number of U-238 Concentrations >Background[a]/Total Number of Samples (%)	Range of Concentrations >Background (1.40 pCi/g)	Wells and Boreholes with Detections >Background
0 to 35	8/13 (61.5)	1/13 (7.7)	5.40	USGS-91
35 to 140	27/44 (61.4)	3/44 (6.8)	1.7 to 5.9	8802D, USGS-94, 76-4
140 to 250	27/39 (69.2)	2/39 (5.1)	2.8 to 7.5	USGS-93, USGS-94
More than 250	0/0	0/0	—	—

a. Background is 1.40 pCi/g (Rood, Hams, and White 1996).

4.6.79.2.7.5 Vadose Zone Core Summary—Uranium-233/234, U-235 and U-238 concentrations appear to be at background levels in core samples. Uranium-233/234:U-238 ratios on the 1999 to 2000 data were representative of natural uranium.

4.6.79.2.2 Lysimeter Samples at Depths of 0 to 35 ft

4.6.19.2.2.1 Uranium-2331234—A total of 122 lysimeter samples collected from the shallow vadose zone were analyzed for U-233/234 between 1997 (beginning of uranium monitoring) and May 2001. Of those, 120 samples contained detectable concentrations of U-233/234 and two samples were assigned data qualifier flags. The results are shown for the shallow lysimeters in Figure 4-48. **A** total of 91 analyses exceeded the aquifer 1E-05 risk-based concentration for U-234 (6.74 pCi/L) used for comparison. The highest U-233/234 concentrations came from lysimeter samples taken from Wells PA01-L15, PA02-L16, and PA03-L33 (near Pad A), and W23-LO8 and W23-LO9 (on the west end of the SDA) and W08-L 13 (near the Acid Pit). Prominent increasing U-233/234 trends were observed in the west end of the SDA (W23), and near Pad A (PA03). Figure 4-49 shows the occurrence of U-233/234 nondetections, detections above background, and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in shallow lysimeters.